HOME OFFICE.—DANGEROUS TRADES COMMITTEE.

SECOND INTERIM REPORT—III & IV

OF THE

DEPARTMENTAL COMMITTEE

APPOINTED TO INQUIRE INTO AND REPORT UPON

110562 ac

CERTAIN MISCELLANEOUS DANGEROUS TRADES.

ELECTRICAL GENERATING WORKS.

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DANGEROUS TRADES COMMITTEE.

COMPOSITION OF THE COMMITTEE.

HAROLD JOHN TENNANT, M.P. (*Chairman*).

MAY EDITH TENNANT, Her Majesty's Superintending Inspector of Factories.

THOMAS OLIVER, M.D., F.R.C.P., Physician to the Royal Infirmary, Newcastle-upon-Tyne.

HAMILTON P. SMITH, Retired Commander, R.N., Her Majesty's Inspector of Factories (*Secretary*).

CHARLES VERNON BOYS, F.R.S., was appointed on the 9th of February 1897 to be an additional Member of the Committee, for the special purpose of assisting the Committee in their inquiry into the Conditions of Work as they affect the Safety and Health of Operatives in Electrical Generating Works.

REFERENCE.

THE COMMITTEE WERE DIRECTED BY THE SECRETARY OF STATE TO INQUIRE INTO THE CONDITIONS OF WORK AS THEY AFFECT THE HEALTH OF THE OPERATIVES IN THE FOLLOWING INDUSTRIES AND PROCESSES :—

*India Rubber Works.
*Paper Staining, Colouring, and Enamelling.
*Dry Cleaning.
Basic Slag Works and Manufacture of Silicate of Cotton.
Electrical Generating Works.
Sole-Stitching by American Machinery.
Glass Polishing.
File Cutting.
*Bronzing and Mettallachrome Powder in Lithographic Works.
Flour Mills.
The Use of Converters in Metal Works.
*The Use of Steam Locomotives in Factories.
Licking of Labels for Reels in Thread Mills.
*The Use of Inflammable Paints in Shipbuilding Yards.
Galvanised Iron Works.
The Process of Dyeing with Arseniate of Soda.
The Manufacture and Use of Grindstones and Emery Wheels.
The Use of Lead in various forms in Print and Dye Works.
The Testing of Bottles by Compressed Air.
*The Bottling of Aërated Waters.
The Manufacture of Salt.
"Ending and Mending" in Velvet Works.

And to report what, if any, special rules should be made under section 8 of the Factory and Workshops Act, 1891, for the protection of the persons employed in these industries.

* These subjects were reported upon in the first interim report of the Committee, 1896.

Second Interim Report of the Departmental Committee appointed to Inquire into and Report upon certain Miscellaneous Dangerous Trades.

To the Right Hon. Sir MATTHEW WHITE RIDLEY, Bart., M.P., Her Majesty's Principal Secretary of State for the Home Department.

Since the issue of their Interim Report of 1896 the Committee have met and considered the subject-matter referred to them; twenty-six generating stations and sub-stations in all parts of the United Kingdom have been visited by one or more members of the Committee. The further sittings of the Committee have occupied 30 days, making a total since their appointment of 94 days; they have examined witnesses in relation to this subject, and have agreed to the following Interim Report, viz. :—

ELECTRICAL GENERATING WORKS.

1. In presenting their Report upon the electrical question the Committee would mention that they have been in consultation with the Board of Trade in order that there should be no division of authority or overlapping of jurisdiction between that Department and the Home Office. The Committee believe that completely harmonious working can be achieved with the least amount of difficulty by the application of the recommendations which follow at the end of this Report to all generating stations and transformer stations into which one or more persons can enter, and that cables or wires outside such stations or chambers should remain, as now, the care of the Board of Trade. The Committee are further of opinion that these recommendations should be applied to all stations and transformer chambers where electric currents are generated or transformed by way of trade, for consumption by the public, or where they are used in any factory or workshop, or in any place of public resort for business or amusement, including Government establishments, shops, warehouses, and theatres, and exclusive only of private houses and premises. For it has been suggested that where corporations or public bodies carry on a generating supply for the public good, such cases might not be considered to come within the scope of the mischief aimed at. The Committee do not admit this argument; they consider it equally important to safeguard the lives of the workers, whether they be employed by individuals, urban corporations, or other public bodies.

2. The Committee have found some difficulty in dealing with electrical generating works in consequence of the technical difficulties of applied electricity. In framing their recommendations, therefore, they have attempted to avoid technicalities as far as possible. In the earlier parts of the Report the Committee have been content with indicating merely in outline the nature of the process and the dangers inherent to it, feeling that anything like an explanation would lead to the writing of a text-book, of which many are already available.

3. The Committee have also met with certain difficulty owing to the great diversity of system which is to be found in different generating stations. In addition to this it is impossible to foresee every accidental combination of circumstances which might lead to serious risk. The Committee would assert that, broadly speaking, the accidents which have occurred are those which are most likely to occur. They believe their recommendations will be found to have provided against such accidents, and others suggested by these fatalities, although they would desire to record it as their opinion that the dangers from electric shock in the generation and distribution of high pressure currents can never be entirely obviated.

4. The Committee would further wish it to be understood that owing to the great increase in the production and consumption of electrical energy in late years, and to the prospective growth and development of the industry the suggestions they put forward in this Interim Report are necessarily of a somewhat tentative nature; and

they wish to take this opportunity of disclaiming for their proposals any element of finality.

At the same time they desire to emphasise that in their opinion it is of the greatest possible importance that the workpeople in electrical generating works and sub-stations should be protected by every reasonable precaution from the grave dangers inherent in these operations. If any confirmation of this opinion were required it will be found by a reference to the schedule of accidents in Appendix I., from which it will be seen that in the last five years fourteen fatal accidents have occurred including five since the appointment of the Committee. But while disclaiming finality for their proposals the Committee would claim for them that they are framed with an earnest desire to prevent a recurrence of the deplorable fatalities which have occurred in the past, with the strong conviction that without these or similar requirements no efficient protection for the lives of the workpeople can be afforded, and with the full belief that the occupiers and employers in this industry, while finding no insuperable difficulty in carrying them out, will be grateful for the relief from responsibility which their acceptance and execution will accord.

5. The Committee desire to express their grateful acknowledgments for the invaluable help they have received from the several gentlemen of eminence and learning who have come forward to assist them. In this manner they have derived information and guidance which it would otherwise have been impossible for them to secure. To Major Cardew, R.E., Electrical Adviser to the Board of Trade, they feel especially indebted, and to Sir David Salomons, Bart., Professor Ayrton, F.R.S., Dr. Hopkinson, F.R.S., Professor Kennedy, F.R.S., Professor Silvanus Thompson, F.R.S., Mr. F. Bailey and Mr. James Swinburne, they take this opportunity of tendering their sincere thanks.

General Remarks.

6. Electrical generating stations may be conveniently divided into three classes, those which supply current (*a*) at low pressure, (*b*) at high pressure, and (*c*) at extra high pressure:—

(*a.*) Currents at low pressure distributed from generating stations are invariably direct, *i.e.*, they flow in one direction only.

(*b.*) Currents at high pressure are either direct or alternating. Alternating currents change their direction a great number of times in a second. A hundred complete alternations a second is very usual.

(*c.*) At present there is in Great Britain only one station at extra high pressure and this supplies alternating current, but either direct or alternating current might be produced at extra high pressure.

(*a.*) *Low Pressure.*

7. When the current is direct and of low pressure, the cables from the generating station have to carry the whole current which passes through the houses, and in order that the resistance to the passage of so great a current may not be serious, very large cables, involving the use of a large quantity of copper, are essential. In scattered districts, especially, the amount of copper necessary would be so great that electric supply under this system could hardly be carried on economically.

(*b.*) *High Pressure.*

8. A method of enabling consumers to be supplied with current greater than that passing through the mains which leave the generating stations is provided where high pressure currents, whether direct or alternating, are employed; thus the essential advantage of high pressure systems, viz., the reduction of the amount of copper in the mains, is attained.

This is effected by means of motor generators or of transformers, which are appliances for converting a small current at high pressure to a large current at low pressure, or *vice versâ*. According to the proportions of the two sets of windings upon them, the current in the consumers' circuit, which it may be stated is not metallically connected with the high pressure mains, is caused to have any desired relation to that passing through the mains. Where, as is usual, the current on the consumers' circuit is ten or twenty times as great as that conducted by the high

pressure mains, the pressure at which it flows is in the same proportion less, and thus it is that, while 100 or 200 volts conveyed into a house is safe, so far as accidental contacts are concerned, a dangerously high pressure is necessary in the mains and generating stations.

Expressing the same thing somewhat differently, the generating stations have to supply the consumer with electrical power; this is measured anywhere on the route by the product of the current and the electrical pressure.* The power in the mains is a certain product made up of a high pressure and a small current, whereas on the consumers', or low pressure, side the same power (neglecting the small loss in the motor generator or transformer) is made up of a greater current and a low pressure. Thus the consumer is supplied with electrical power at a safe pressure, while the producer can transfer it from the station by a comparatively thin cable, because a small current only is necessary if the pressure is high, and the losses in the cable depend upon the current, and not upon the electrical power supplied.

(c.) *Extra High Pressure.*

9. Owing to the fact that in this country there is only one station on this system, the Committee do not feel that any generalisation could safely or fairly be deduced from a single example; and, beyond stating that the danger of 10,000 volts is out of all proportion greater than that of five times 2,000 volts, they do not propose at present to deal with this branch of the subject. But they understand that projects are on foot for employing 10,000 volts, or some other number constituting extra high pressure, in connection with electric railways. When these schemes have assumed more definite shape the Committee feel that Special Rules will have to be drafted and issued for the protection of the work-people employed.

The Process.

10. The primary source of power in this country is almost invariably the combustion of coal, oil, or gas, which is converted into mechanical power by steam, oil, or gas engines. Any of these may be employed to drive machines which are known as dynamos, and which convert the mechanical into electrical power. The electric current is directed into the proper channels at the switchboard, and conveyed along the conducting cables or mains into the districts served by the generating station.

11. There are many forms of dynamo, but in every case there must be a field-magnet and an armature, either of which is made to revolve. In consequence of the rotation of one or other, currents are induced in the armature. If the armature is stationary these may be led away by cables directly connected to the terminals of the armature. In this case the current is necessarily alternating. If, on the other hand, it is the armature which revolves, direct connection between the armature terminals and the cables is impossible. For this reason sliding contact between fixed collectors or brushes and conducting rings or commutator strips upon the shaft of the armature is required to convey the current to the cables. Where conducting rings are used the current is necessarily alternating; but where a direct current is intended the commutator strips are employed.

12. The switchboard is a structure which enables the electrician in charge readily to make any of the changes in the electrical connections between the dynamos, cables, fuses, and measuring instruments, which the ordinary working of the station may require.

13. Cables of various forms and make are employed to conduct the electric current from the generating stations to all parts of the district served. In those cases where the cable is conducting at low pressure, as in low pressure systems, and in the low pressure branches of high pressure systems, no danger is to be expected; to these cables, therefore, no further reference need be made.

High pressure cables generally consist of stranded copper wire. When they are to be laid underground, this is invariably coated with insulating material. The

* All reference to the intricacies of phase difference in the alternating system is purposely avoided.

two conductors necessary for the passage of the current from and to the station may consist of two distinct insulated cables, but what are known as concentric mains enable a single cable to serve the double purpose. Conductors which are fixed overhead, and which are usually known as aërial cables, are often bare over their entire length. This is more likely to be the case within the curtilage of a factory, where the Board of Trade rules do not apply.

14. The motor generators or transformers, the purpose of which has been indicated above (para. 8), are placed in "substations." These may be rooms of considerable size; chambers in which there is space for one or two people in addition to the transformers, or mere boxes practically filled by the transformer. Transformers are sometimes placed in cellars or other parts of the consumers' premises.

The motor generator is a combination of motor driven by the energy of the current in the high pressure mains and a dynamo generating the low pressure current of the local circuit. If the current is alternating, branches from the mains are connected to the primaries of transformers which supply the local circuits. In both cases fuses are inserted in the circuits in various places proportioned to the heaviest current that can properly be allowed to pass, so that if by accident an excessive current should arise, the fuse will melt and disconnect the circuit.

15. In addition to the ordinary transformer and motor generator, already referred to, there are contrivances of many different kinds known as "rotary converters," "boosters," &c. by means of which a current may be converted from direct to alternating, or the reverse, or may have its pressure altered or adjusted in any direction.

Uses of the Electric Current.

16. Either alternating or direct currents are supplied from generating stations to private consumers for domestic and general use. For arc lighting also, and for driving motors, either a direct or alternating current may be employed. The same is true where the current is used for electric heating, electric welding, and electric furnaces.

For charging secondary batteries, however, and for various electrolytic manufacturing operations, direct currents are used, and ordinarily at low pressure.

The Dangers of Working.

17. The dangers inherent in steam and other motive machinery, being well known and provided against by the general law relating to factories, do not require consideration in this report.

18. In the handling and preparing of plates for storage batteries, risks of lead poisoning exist; but the workers are already protected by the special rules framed for "Electric Accumulator Works;" beyond this no special dangers to health have been noticed. There is, however, a risk in the use of these accumulators in consequence of the evolution of an explosive mixture of gases when the plates are overcharged. Where the ventilation is very imperfect, a quantity of gas may accumulate sufficient to take fire or explode on contact with a spark or flame.

19. The danger peculiar to electrical generating works is the liability to shock, which is often fatal if, by accident, anyone comes into contact with the conductors when charged to a high pressure. The contact need neither be very perfect nor direct; provided two parts of the body are made to touch conducting materials which themselves differ in pressure by 1,000 volts or more, or even by much less if the contact with the flesh is very good, a dangerous and possibly fatal shock will result. The ground, especially if damp, is sufficient for one of the contacts, damp leather boots affording no protection, so that anyone standing on the ground or on metallic or damp wood flooring cannot safely touch a single object charged to a dangerous pressure. If, however, he should be standing upon a dry indiarubber mat, which is an excellent non-conductor, he will come to no harm on touching any number of dangerously charged bodies which are at the same electrical pressure; but if he should simultaneously touch, even through his clothes, two bodies which differ from one another in pressure by about 1,000 volts, the actual amount depending largely on the perfection of the contact, or if, while safely touching highly charged metal, he

should touch or pass by hand any conducting article to someone else who is not also insulated, then a fatal shock may follow.

20. The metal which is highly charged and which would be liable to be touched, if not properly protected, is to be found in the dynamo machines, the switchboard and its metal connections, the high pressure mains, and the transformers, and, in the case of series arc lighting, in the lamps themselves.

21. In alternate current dynamos with fixed armature and rotating field-magnet, the terminals of the machine to which the cables are connected are the only parts which could well be left exposed, and these are so easily boxed in that the most negligent user would hardly leave them unprotected. On the other hand, when the field-magnet is fixed and the armature revolves, there are on the shaft two contact rings which form the terminals of the armature, and the terminals of the machine are connected with these by two brushes. In this case the terminals of the machine can just as readily be protected as in the last, but there are in addition the contact rings and brushes. These may require attention either at starting or during the running of the machine, or they may be a source of danger if the attendant, in oiling with a metal can or working with ordinary tools, brings any of these accidentally in contact with the highly charged metal.

In the case of direct current dynamos, the commutator and brushes take the part of the contact rings and brushes in the alternator with moving armature, and what has been said before applies equally to both.

22. The switchboard should be easily and quickly accessible on the front, where all the ordinary operations of connecting and disconnecting the various dynamo machines and cables are effected. The back should be inaccessible, except to those skilled persons who have the right and means of entry. Here each cable end and conductor from the dynamos is connected to its appropriate block of metal. These blocks are generally exposed for convenience of repair and alteration. None of the every day work of the switchboard is carried out here, so that the risk of accident can only exist when alterations are being carried out within reach of highly charged metal.

There is no necessity for any metal directly connected with the high pressure mains or dynamos to be exposed on the front or working face of the switchboard to accidental contact.

23. High pressure main conductors may be erected as overhead wires, but are almost universally laid underground.

Bare overhead high pressure conductors may lead to accident in case of breakage or by swinging into contact with buildings, &c., under the action of the wind, or by earthing at the points of support in consequence of damage to the insulators; or they may become sources of danger to persons who unintentionally put themselves in contact with them by a ladder or other means. High pressure overhead wires, even if insulated over their entire length, can never be considered as entirely free from risk.

In underground cables the insulation which is employed to prevent loss of current will, when it is perfect, *i.e.*, undamaged, amply protect anyone touching it from any dangerous pressure from the metal within, but an injury which would not be sufficient to be detected in ordinary working might nevertheless allow of the escape of sufficient current to produce instantaneous death. As the cables are liable to injury when being drawn in, workmen who handle mains charged to high pressure with their bare hands may be injured or killed.

Concentric mains are often employed with a central high pressure wire or cable, and an external group of wires insulated from the central cable. The outer wires are in general insulated again, and the whole is often enclosed in a lead tube. If the outer conductor is efficiently connected with earth at the generating works, no part of it will attain a dangerous pressure, and the risk of handling such a cable is greatly reduced.

24. Transformers and the metal cases in which they may be enclosed, if not efficiently connected to earth, are a source of danger in the event of "running to frame," or of any deficiency in the insulation of the high-pressure wire or cable. If there is any moderate insulation leakage the earth-connected case cannot become charged; or if the insulation fail, and the high-pressure main becomes connected with the casing, the extra strong current resulting will blow the fuse in the transformer or its chamber, or at the central station, and disconnect the faulty part from the circuit. So long as no highly-charged metal is exposed, and the conditions indicated are correctly fulfilled, it would appear almost impossible for accidents to occur to men at work outside the transformer casing.

25. By efficient earthing is meant metallic connection to some good conductor which is in contact with damp soil over a considerable area. An earth cannot be considered efficient unless, under all weather conditions, in case of accidental contact with metal charged to high pressure, it will secure the passage of a current sufficient to blow the fuse employed for the protection of that metal. The best earth often available is the system of cast-iron pipes, through which the cables pass, provided all the joints are metallic. A mere bolt or rod in brickwork, concrete, or in the ground, especially when that is liable to become dry, would be useless as an efficient earth in the case of metallic connection with high-pressure supply; but it might be sufficient to discharge the very small leakage that would occur with sound and, ordinarily speaking, perfect insulation. Transformers become warm in working, and thus the chambers, especially if well ventilated, are apt to become very dry.

26. Arc lights, when supplied with current from a central station, are usually arranged in series, *i.e.*, the same current is sent through a number of lamps. As an arc lamp requires an electrical pressure of from 40 to 50 volts, dangerous pressure becomes necessary when several lamps are arranged in series, for the electrical pressure is the sum of the electrical pressures of all the lamps separately. A workman who is himself insulated cannot obtain a serious shock by handling even the two terminals of any single arc light, but if he is not insulated, and he touches any charged part of an arc light, a current may pass through his body; this may or may not be dangerous in itself, but, in consequence of the fact that these lamps can in many cases only be reached by means of a ladder, a shock, harmless in itself, may cause a man to lose his hold and be seriously injured. If the whole electrical system is perfectly insulated, the shock depends upon the accidental pressure of the particular lamp touched; if, however, the insulation of the system, at any part which differs greatly in pressure from the lamp touched, be defective, then a dangerous shock is certain to follow.

27. As illustrating the dangers incidental to the use of electricity it has been stated that in addition to minor accidents, of which we hear little or nothing, 14 deaths have been reported since 1892. The effects of the passage of an electric current through the human body are extremely uncertain and variable. Whilst the pressure required to cause death has in America been fixed at 1,500 volts, it is clear from the evidence laid before the Committee that a smaller pressure may prove fatal, provided circumstances are favourable to the passage of the current through the body. People are known to have been accidentally brought into contact with higher pressures than 1,500 volts without any serious consequences following. These cases illustrate the extreme uncertainty and variableness indicated above. If a person receives a powerful electric shock his muscles are thrown into such a state of tetanic rigidity that it is impossible for him to relax his grasp or extricate himself from his dangerous position. Such a shock may simply stun the person who receives it, rendering him unconscious for a brief period; it may, however, burn him, charring the surface of the body and inflicting deep wounds which heal with difficulty, or, as is usual where the pressure has been great and the conditions of resistance slight, it may cause sudden death. It is believed that strong electric currents may cause death in one of two ways (*a*) either by arresting the breathing, or (*b*) by suddenly stopping the heart. With the view of ascertaining the cause of death, and of devising and testing means for resuscitation, Dr. Oliver undertook a series of experiments upon animals, most of them under the influence of an anæsthetic. Although in nearly all instances death was due to arrest of the heart's action, it is impossible to say upon which organ the current primarily exerted its harmful influence. In attempting to resuscitate them, the one method which above all others gave the most satisfactory results was *artificial respiration*. By this means some of the animals recovered even though the heart had ceased beating for a period, in one instance for as long as 13 minutes. Artificial respiration, therefore, should in all cases of apparent death from electric shock be resorted to at once, and persisted in for a considerable time, for recovery is known to have taken place where it has been practised for fully half an hour. Since this is the best treatment at our command, and every minute passed after finding a body in a perilous position without any attempt at restoration diminishes the chance of recovery, it is desirable not only that workers in electrical generating and distributing stations should be made thoroughly cognizant of the dangers incidental to their calling, but should receive practical instruction in methods of treating suspended animation.

The rules subjoined in Appendix II., furnished by the Editors of the "Electrical Review," supply the required information. The Committee desire to express to the editors the gratitude which they feel for this courtesy and for other assistance.

Recommendations.

28. For the purposes of these regulations a station where the direct current generated is at 700 volts or any higher number, or where the alternating current generated is at 350 volts or any higher number, shall be considered a "high pressure station," and all metal conductors, whether they be on the dynamos, the switchboard, the mains, or any other part of the station carrying a current at a pressure equal to or greater than that above-mentioned shall be deemed to be at "high pressure."

The Committee recommend that the following regulations should be applied in all those cases mentioned in Paragraph 1 where electricity at high pressure is in use. It is not intended that they should be applied to low pressure systems:—

(i.) The frames and bed-plates of all generating machines shall be efficiently connected to earth.

(ii.) The rails fencing dynamos, or other generating machines, shall be made of wood or other non-conducting material.

(iii.) All terminals, collecting brushes, main connectors, parts of dynamos, motors or other appliances, to which neither Regulation No. (vi.) nor No. (vii.) applies, shall be so placed, covered or fenced with non-conducting materials, that no person can touch accidentally, either with his body, clothing, or any conducting tool, two parts differing from each other by an amount which constitutes a high pressure. This rule is to be read in connection with No. (iv).

(iv.) The floors of all places where it would be possible to make connection with metal at high pressure shall be covered with an insulating mat of suitable material and kept in a state of efficient insulation.

(v.) The material used for wiping or cleaning the commutator strips or collector rings of dynamos, motors or rotary converters of any form shall be applied by means of an insulating handle.

(vi.) In switchrooms and on the front of switchboards, the main switches, main fuses, main terminals, omnibus bars, and all other metallic parts shall be insulated or arranged in such manner as to render it impossible for any person by accident or inadvertence to touch them.

(vii.) The backs of all switchboards shall be kept closed, except for the purpose of alterations or repairs. When such work has to be carried on either at the back or at the front of switchboards, the following regulations shall apply:—

a. No person except a skilled electrician, or a workman under his personal and immediate supervision, shall be employed when any part is at high pressure.

b. No extensive or serious repairs shall be executed upon metal which is at high pressure.

c. Where the alterations or repairs are not of an extensive or serious character all metallic parts at high pressure shall be covered with an insulating cap or protected by some form of insulating covering, only one part, or several at the same pressure, to be exposed at any one time.

(viii.) All switchboards erected after the application of these Rules shall have, at the back, a clear space of at least four feet. This space shall not be utilised as a store room or lumber room, or be obstructed in any manner.

(ix.) Any person at work upon a cable or portion of the mains under high pressure shall wear india rubber gloves on both hands.

(x.) All aërial high pressure conductors in factories or workshops shall either be insulated over their entire length, and supported at such frequent intervals that, in the event of breakage, they shall not come within reach at places where persons are liable to pass or to be employed, or shall be so placed and arranged as to comply with the requirements relating to such wires in streets enjoined by the Board of Trade.

(xi.) The gloves shall be supplied by the occupier, and it shall be the duty of the manager to see that they are in a proper state of repair, and are worn by the workpeople.

(xii.) No examinations, repairs, or alterations necessitating the handling of mains, wires, machines, or other apparatus, shall be carried on except in cases of urgent necessity while such parts are under high pressure, and all such work shall be done under the personal supervision of an electrical engineer or competent manager or foreman.

(xiii.) Where operations are being conducted upon mains from which the current has been cut off, the switch shall be locked and precautions taken that it shall not be unlocked except by the person in charge of the station on his being satisfied that the danger is at an end.

(xiv.) Every vessel used for lubricating purposes shall be so constructed that it cannot act as a conductor between the hand and anything touched.

(xv.) Metal transformer boxes shall be efficiently connected to earth, and so constructed that in the event of "running to frame" the earth connection will not be broken by the removal of the fuse box or any other part of the box.

(xvi.) Transformer cases, iron ladders, and all permanent metallic parts contained within the transformer chamber, and not forming part of the electric circuit, shall be metallically connected together.

(xvii.) All holes in transformer cases, through which high pressure conductors pass, shall be lined or bushed with suitable and effective non-conducting material.

(xviii.) All high pressure connections within a transformer chamber shall be so protected with insulating material that it shall be impossible to touch them.

(xix.) Switches which can be conveniently operated from the outside for cutting off both the high and low pressure connections of the transformers shall be fitted in all transformer chambers erected after the application of these Rules, and in all existing chambers, unless it is proved to the satisfaction of Her Majesty's Chief Inspector of Factories that such an arrangement would be attended by special difficulty.

(xx.) Each post or support where series arc lighting is employed shall be provided with means for completely disconnecting the arc lamps from the mains, without disturbing the action of the other lamps.

(xxi.) All persons engaged in electrical works shall be made fully aware of the dangerous parts of the machinery, cables, and their connections, and shall be practically instructed in methods of artificial respiration—that known as SYLVESTER'S is both simple and efficacious. Rules for artificial respiration, and for the restoration of persons apparently killed or injured, shall at all times be kept affixed in the station. All persons engaged in the works shall thoroughly understand these rules and be capable of putting them into practice. In the event of a person being rendered unconscious by an electric shock, artificial respiration shall, on the careful removal of the body from its electrical contact, be at once resorted to, and a qualified medical man immediately summoned.

(xxii.) All accidents occurring in generating stations or transformer chambers shall be notified according to the provisions of section 18 of the Factory and Workshop Act, 1895.

29. The Committee feel that any set of Special Rules framed for the safety of the workpeople in this industry must imperfectly realize their object if a specially qualified person be not retained to advise the Secretary of State or Her Majesty's Chief Inspector of Factories on matters requiring technical knowledge of electricity.

H. J. TENNANT.
MAY TENNANT.
THOMAS OLIVER, M.D.
C. V. BOYS.
H. P. SMITH.

The Committee desire to express their deep sense of obligation to Mr. Boys, F.R.S., for the invaluable assistance he has rendered them in the course of their inquiries, and in the drafting of this Report.

For the Committee,
H. J. TENNANT.

APPENDIX I.

FATAL ACCIDENTS from ELECTRIC SHOCK in the last five years.

Date and Place of Accident.	Where Employed.	Occupation at the time of Accident.	Nature of the Fault which Caused the Accident.	Pressure in Volts.
1. March 4, 1892—Chatham.	Near a transformer in a cellar on the consumer's premises.	*Attempting to assist a servant of the Electric Company suffering from a severe, though not fatal, shock.	1. Transformer on the consumer's premises with an imperfectly protected high-pressure wire. 2. Defective aerial cables. 3. Failure of the servant to use the gloves which were provided.	2,400
2. Nov. 9, 1892—Kensington, London.	On a surface-box in the street (Roland Gardens).	Deceased was pulling back the slack on an insulated live main cable.	Failure to use the gloves which were provided.	2,000
3. Feb. 8, 1893—Brighton.	At the front of the switch-board in the central station.	Touching both exposed terminals while manipulating a switch.	The connecting metal strips, although at the back of the ebonite slab, were so placed as to be most liable to be touched by the fingers of the two hands, in case of the failure of the handle provided.	2,000
4. Sept. 12, 1893—Blackfriars.	In the distributing station of the extra high-pressure system.	*While in charge of the station attempting to remove a servant of the company from contact with a charged omnibus bar.	1. Omnibus bar was not discharged - 2. Omnibus bar was not fenced.	2,400
5. June 30, 1894—Blackfriars.	In the distributing station of the extra high-pressure system.	Binding a cable to a terminal with wire, close to a highly-charged omnibus bar.	1. Omnibus bar was not discharged - 2. The space was too confined. 3. The employment of an unskilled workman upon dangerous work.	10,000
6. July 6, 1894—Prescot.	In the dynamo room of the central station.	While employed in regulating the speed of the engine driving the dynamo, the deceased is supposed to have grasped the charged volt-meter wire, which he broke.	The highly-charged volt-meter wire appears to have been insufficiently protected.	2,000
7. Sept. 30, 1894—Bankside.	On a switch-pillar in the central station.	Deceased went up a ladder and came in contact with some high-pressure metal ordinarily out of reach.	—	2,000
8. Nov. 26, 1894—Taunton.	In the dynamo room of the central station.	Oiling the bearings of an alternator machine, the bed of which was earthed. It is supposed that a short circuit was set up by the oil-can.	1. Guard-rails fencing the machine were not made of insulating material. 2. The oil-can was made of metal unprovided with an insulating handle.	2,000
9. Feb. 26, 1895—Bristol.	On a transformer chamber in a cellar.	Dusting a high-pressure fuse board with an ungloved hand.	1. Fuses and terminals were, from their position, dangerous and unprotected. 2. Work was being done while the current was not switched off. 3. Only one glove was worn. 4. The floor was of cement, and was damp.	2,000
10. Dec. 16, 1895—Cheltenham.	On a transformer chamber in the street.	Deceased was cleaning or repairing some part of the transformer chamber, when his elbow came in contact with a high-pressure terminal.	The high-pressure terminals were so placed as to be dangerous, and were unprotected.	2,000
11. Jan. 21, 1896—Hampstead.	At the back of the switch-board in the central station.	Making alterations, when he accidentally came in contact with two metallic connections charged to different pressures.	1. The exposure at one time, without protection, of metallic parts charged to different pressures. 2. Want of space at the back of the switch-board.	2,000
12. May 15, 1896—Bedford.	In a transformer chamber in the street.	About to examine the terminals in the chamber, the deceased lifted the fuse-box from the top of the transformer, thus breaking the earth connection of the transformer casing.	Defective insulation of the high-pressure mains, which might have been obviated by having the hole in the transformer casing bushed with effective insulating material.	2,000
13. Jan. 23, 1897—Newcastle-on-Tyne.	On centrifugal pumps in a factory.	Deceased was carrying an iron ladder which became entangled in the connections of an arc lamp.	—	1,000 on a 3,000 volt circuit.
14. March 6, 1897—Hampstead.	In a transformer chamber in the street.	Deceased was descending an iron ladder, and put one foot on the transformer, which had become highly charged.	1. Insufficient earth connection from the transformer casing. 2. Defect in the insulation of the main cable, which might have been obviated by having the hole in the transformer casing bushed with effective insulating material, or by having the outer wire of the concentric cable earthed at the central station.	2,000

* It will be observed that in these cases the deceased was attempting to assist someone else who had met with an accident.

APPENDIX II.

THE "ELECTRICAL REVIEW'S" SUGGESTIONS FOR DEALING WITH APPARENT DEATH FROM ELECTRIC SHOCK.

The following suggestions are based on the recommendations of Drs. D'Arsonval, Goelet, Hedley, and Lewis Jones for the treatment of persons apparently killed by electricity:—

Apparent Death.

In many cases where persons receive electric shocks, death is only apparent, and animation may be restored if efforts at resuscitation are not too long delayed.

Method of Resuscitation.

The method of resuscitation resorted to should be that known as artificial respiration.

Efforts to induce respiration should not be relaxed until breathing is fully and normally restored, or until it is absolutely certain that life is extinct.

Danger of Seizing the Victim's Body.

If the accident has been due to contact with a "live" or faulty cable, the injured person may retain a grasp of it. When the injured person retains his hold of the cable it is dangerous to seize any part of him, even the parts of the body covered by clothes.*

Perspiration may make the clothes damp and render them good conductors, especially under the armpits, which would be the part most likely to be seized.

In such a case the person who goes to the assistance of the victim should protect his hands, whenever possible, with india-rubber gloves.

Where gloves are not available, a thick layer of dry rags might be used to cover the hands, or a coat or any other garment, if made into a thick pad, might be used when pulling the victim away from the cable or machinery.

Send for a Medical Man at once.

No time should be lost in sending for a qualified medical man, but in the meantime the following efforts should be made to restore animation.

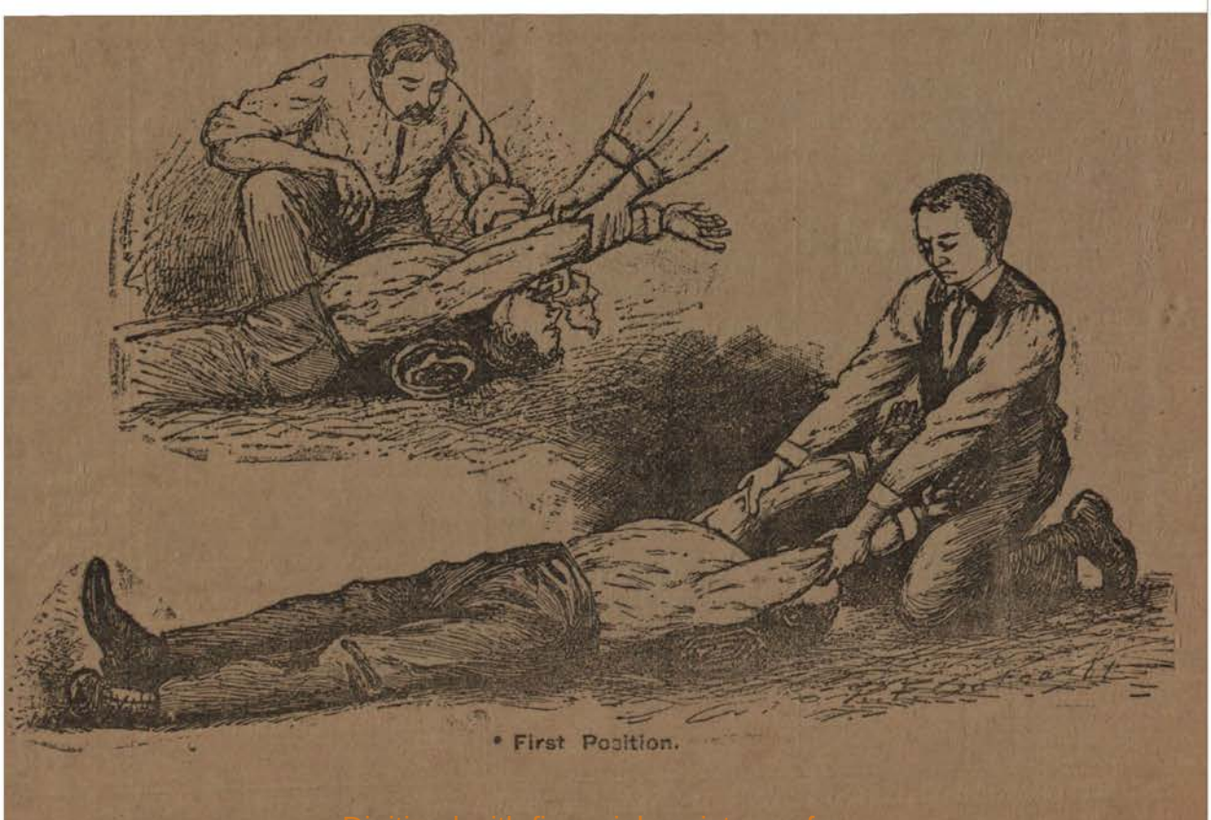
How to Place the Body.

The body should be at once placed upon the back and the clothes loosened. A roll made of a coat or anything else convenient should then be placed under the shoulders. It should be sufficiently large to prop up the spine so that the head drops backward (*see* illustration).

Position of the Operator.

The operator should kneel behind the subject's head, in the manner shown in the illustrations. He should then grasp the elbows and draw them well over the head, so as to bring them almost together above it, and hold them there for two or three seconds. Then he should carry them down to the sides and front of the chest, firmly compressing the chest by throwing his weight upon the arms.

* To show the importance of following this injunction it is only necessary to mention an accident recorded in the "Electrical Review." While a man was cleaning an electric street lamp at Boston he received a shock and was killed, his body being suspended from the wires. A man who endeavoured to remove the body came in contact with it, and was dashed to the ground with such violence that he died shortly afterwards.



* First Position.

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After two or three seconds the arms should be again carried above the head, and the operation repeated at the rate of about 16 times per minute.

Additional Means of Resuscitation.

In addition to the foregoing, if there be an assistant at hand, the tongue should be seized by a cloth or handkerchief and drawn forcibly out during the act of inspiration, *i.e.*, when the arms are extended above the head; when the arms are brought down, the tongue should be allowed to recede. This operation should be repeated with the same regularity as the movement of the arms.

Stimulants to be Avoided.

According to Dr. Hedley the efforts of the bystanders to pour stimulants down the throat of the victim should be resisted until a medical man arrives.

Necessity of Deliberation.

It should be borne in mind that to be successful the foregoing operations should be carried out deliberately and methodically. There should be no haste, but the operations should be executed vigorously.

In many respects the treatment suggested above is similar to the method of treating apparent death by drowning.

* Second Position.

* These blocks were reproduced from some which appeared in the "Electrical World" of New York.